Water Resources

EES has been leading projects to better understand and quantify many of the components of the water cycle that affect water resources, including surface and subsurface flow, precipitation, surface sediment and contaminant transport, and subsurface contaminant transport. We play a major role in understanding the variability of these processes and their connections to global and regional climate change. As part of the Coupled Environmental Modeling project, we generate high-performance computing models of the regional water cycle to understand the effect of changes in climate and/or land use on water resources. We also support the Los Alamos ER project. For ER, we have used the watershed-scale model SPLASH (Simulator for Processes of Landscapes, Surface/Subsurface Hydrology) to examine the runoff relationships between mesas and canyons; KINEROS (Kinematic Runoff and Erosion Model) to predict soil erosion and contaminant transport; and a 2-D flow and transport model to predict present and future contaminant migration.

Developing a Flow-and-Transport Model of the Regional Aquifer Beneath the Pajarito Plateau

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Los Alamos is engaged in a multiyear program to characterize the regional aquifer beneath the Laboratory and to predict the migration of contaminants from their sources to potential receptors (water-supply wells). To support this program, we are developing a flow-and-transport model of the regional aquifer. We have calibrated steady-state and transient flow models, providing predictions of solute transport.

The extent of our model is the Española Basin, a sub-basin within the Rio Grande rift. To account for the influence of complex hydrostratigraphy within the basin, we developed a 3-D hydrostratigraphic framework model for the basin. To accommodate the higher grid resolution required by transport calculations, we have generated a second grid with increased resolution in the vicinity of the LANL site. We designed the framework models and grids to be easily modified as new data are collected from deep wells.

To compute steady-state flow solutions, we used the Los Alamos computer code FEHM. By varying permeabilities within measured ranges and comparing model predictions to observed water levels, we arrived at an initial calibration using automated parameter-estimation software (PEST). For most wells in the basin, and for all wells near the plateau, we accomplished a reasonable calibration using acceptable values for permeability. We have also integrated solute transport and water chemistry data into the flow model calibration process.

In response to the detection of high explosives in groundwater near Laboratory site TA-16, we developed a transport model to predict pathways and travel times within the regional aquifer. Heterogeneity within the most critical rock unit is modeled stochastically. Our model predicted that HE originating near TA-16 and/or in the subsurface along Canyon de Valle would eventually reach water supply wells PM-2 and PM-4; median travel times are expected to be 200–300 years. As the deep drilling program progresses and we gather more hydrologic data, we expect to reduce the uncertainty in our pathway and travel time estimates.

Modeling Spatially Explicit Runoff and Erosion in the LANL Area

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Although many contaminant-related risk assessments focus on evaluating risk associated with a single site, many scenarios exist for which contamination must be assessed from multiple sites. We are studying such a contamination scenario, using the north Ancho Canyon watershed in the LANL area as a test case. Using the computer code SPLASH, we modeled the lateral flow of surface and subsurface water following a 100-year precipitation event (intense thunderstorm) in the north Ancho watershed. We then ranked the vulnerability to surface and subsurface flow of sites within the watershed.

We found that for the 100-year event, surface flows generally exceeded subsurface flows by more than four orders of magnitude, indicating the relative importance of potential redistribution of contaminants by surface runoff. Of the 18 potential contaminant release sites that would be reached by the flows, the maximum surface flow within any given potential release site (PRS) varied by more than an order of magnitude across the PRSs. Half the PRSs had surface flows of less than 25 percent of the maximum surface flow for a PRS, which allows us to identify, prioritize, and remediate the most vulnerable sites.

To evaluate erosion, we used the event-based model KINEROS. Using data from our pilot studies, we calibrated and tested the KINEROS code for runoff and soil loss, and we applied the parameters to an event at Area G, the Los Alamos low-level radioactive waste disposal site. Our results quantify under what condition runoff increases and demonstrate a means for providing a more quantitative basis for assessing the relative importance and/or vulnerability of widely dispersed contaminated sites within a watershed.

Ecological and Hydrological Interrelationships in Semiarid Ecosystems

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In coming decades, global climate changes are expected to produce large shifts in vegetation distributions, at unprecedented rates. These shifts are expected to be most rapid and extreme at ecotones, the boundaries between ecosystems, particularly those in semiarid landscapes. Unfortunately, current models of global climate change do not adequately provide for such rapid effects—particularly those due to mortality of plant life, largely because of the lack of data from field studies. We recently developed a conceptual model for the transition from low- to high-erosion states in semiarid ecosystems to explain a rapid landscape shift, which has persisted for 40 years and is caused by severe drought in northern New Mexico. The rapidity and the complex dynamics of the persistent shift point to the need to represent more accurately these dynamics, especially the mortality factor, in assessments of the effects of climate change. Additionally, vegetation dynamics and associated hydrological changes need to be factored into assessments of contaminant mobility, landfill cover design, and long-term stewardship plans.

Long-Term Risk from Actinides in the Environment: Modes of Mobility

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In this project we address the relative roles of wind erosion, water erosion, and vertical migration in actinide mobility, using results of our field and laboratory studies and our models of several areas. Our objective is to provide DOE with data and tools that improve risk assessments, cut cleanup costs, and facilitate technology transfer. We have three major results: (1) Our equilibrium-type models indicate that the relative importance of actinide transport by wind erosion, water erosion, and vertical migration differ among and between sites, and these differences exceed more than an order of magnitude within and across sites. These results can be used to prioritize efforts to improve risk assessments and remediation. (2) Results of our field studies demonstrate that disturbances that reduce ground cover, such as fire or heavy grazing, can increase wind and water erosion by more than two orders of magnitude. It is clear that we need to factor in disturbance events and recovery rates into long-term assessment of actinide mobility. (3) Three pathways are driven by low-frequency extreme climatic and disturbance events that greatly increase transport rates relative to long-term averages. These results highlight the need to account for extremes in climate and disturbance that occur on a finer time scale but may contribute most to long-term risks.

Coupled Environmental Modeling: Regional Water Resources

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To optimize the use of limited water resources, particularly in arid and semiarid regions, it is important to understand the entire hydrologic cycle. Supported by the Los Alamos Coupled Environmental Modeling Initiative, we are linking a suite of environmental models to simulate the hydrologic cycle in river basins, using the Rio Grande Basin as a test case. We are using three codes: RAMS to model meteorological variables; SPLASH to partition precipitation into evaporation, transpiration, soil water storage, surface runoff, and subsurface recharge; and FEHM, a code originally developed at Los Alamos for the Yucca Mountain Project, to integrate groundwater effects. We link our FEHM models to both RAMS and SPLASH. FEHM is linked to SPLASH to simulate saturated and unsaturated flow and the artificial and natural effects on the groundwater. We simulate aquifer recharge to and discharge from the river by coupling models generated using RAMS and FEHM.

Our test case, the Rio Grande, flows through semiarid and arid lands in Colorado and New Mexico and along the Texas-Mexico border. It provides an essential water supply in areas in which water resources are already stressed and surface water and groundwater are conjunctively used to supply water needs. The upper portions of the river are primarily fed by melting snow from winter storms. In contrast, the lower portions of the river accumulate runoff from summer monsoons. Thus, the Rio Grande basin is impacted by two regional climates and could be vulnerable to climate change in either area. Our model simulates potential changes to the hydrologic cycle within the entire Rio Grande basin. It can be used for future scenarios of global climate change or modified water use practices.

Establishing the Optically Stimulated Luminescence (OSL) Facility

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The ability to date geologic materials has revolutionized our ability to understand natural processes and their rates of evolution. Until recently, the primary dating method (chronometer) available was carbon-14, a method that isn't reliable for dating current or recent (few hundred years) processes. This early time period is our time frame of intense interest, as we try to understand the impacts of modernized agriculture, overpopulation, or recent climate change on the rates of processes that include cycles of drought and flood, soil denudation, and the infilling of bays, rivers, and estuaries with polluted sediments.

Within the last 10 years a new sediment-dating technique has emerged. Termed OSL, this technique is ideally suited to dating these modern processes. We are now establishing an OSL dating facility at Los Alamos, and we will begin applying this technique to material transport problems in July 2001. OSL estimates are based on the time that has elapsed since buried sediment grains were last exposed to sunlight. The release of trapped electrons by light stimulation resets the OSL signal to zero. When the grains are buried they begin to accumulate a trapped-electron population, caused by ionizing radiation from the decay of radionuclides in the deposit. The burial time of the grains can be determined by measuring the dose stored in the grains, divided by the flux of ionizing radiation (the dose rate).

At the OSL dating facility, we will study environmental problems related to DOE laboratory operations, as well as to more fundamental problems related to Earth surface processes. Some of the questions that we will address include (1) How fast are adsorbed contaminants moving from LANL source areas to canyons and the Rio Grande River system? (2) What size flood event is required to move significant amounts of contaminated sediment out of canyons and into the Rio Grande River system? (3) How far does sediment travel during a flood event? (4) How often do big floods occur in the region of the Pajarito Plateau? (5) How often does movement occur on the Pajarito fault line? (6) How has the rate of erosion changed in Bandelier National Monument since human habitation, and what was the impact of drought and the introduction of grazing?